Appended Note.—It was constantly found that in using a non-corrodible anode such as platinum, the amount of current passing was very much more easily regulated by varying the size of the anode than that of the cathode, with a corrodible anode however, such as silver, this effect was not observed.

THE ETHER AND ITS FUNCTIONS[1]

II.

Consider the effect of wind on sound. Sound is travelling through the air at a certain definite rate depending simply on the average speed of the atoms in their excursions, and the rate at which they therefore pass the knocks on; if there is a wind carrying all the atoms bodily in one direction, naturally the sound will travel quicker in that direction than in the opposite. Sound travels quicker with the wind than against it. Now is it the same with light: does it too travel quicker with the wind? Well that altogether depends on whether the ether is blowing along as well as the air; if it is, then its motion must help the light on a little; but if the ether is at rest no motion of air or matter of any kind can make any difference. But according to Fresnel's hypothesis it is not wholly at rest nor wholly in motion; the free is at rest, the bound is in motion; and therefore the speed of light with the wind should be increased by an addition of $\left(1 - \frac{1}{\mu^2}\right)$th of the velocity of the wind. Utterly infinitesimal, of course, in the case of air, whose μ is but a trifle greater than 1; but for water the fraction is 7-16ths, and Fizeau thought this not quite hopeless to look for. He accordingly devised a beautiful experiment, executed it successfully, and proved that when light travels with a stream of water, 7-16ths of the velocity of the water must be added to the velocity of the light, and when it travels against the stream the same quantity must be subtracted, to get the true resultant velocity.

Arago suggested another experiment. When light passes through a prism, it is bent out of its course by reason of its diminished velocity inside the glass, and the refraction is strictly dependent on the retardation; now suppose a prism carried rapidly forward through space, say at the rate of eighteen miles a second by the earth in its orbit, which is the quickest accessible carriage; if the ether is streaming freely through the glass, light passing through will be less retarded when going with the ether than when going against it, and hence the bending will be different.

Maxwell tried the experiment in a very perfect form, but found no difference. If all the ether were free there would have been a difference; if all the ether were bound to the glass there would have been a difference the other way; but according to Fresnel's hypothesis there should be no difference, because according to it, the free ether, which is the portion in relative motion, has nothing to do with the refraction; it is the addition of the bound ether which causes the refraction, and this part is stationary relatively to the glass, and is not streaming through it at all. Hence the refraction is the same whether the prism be at rest or in motion through space.

An atom imbedded in ether is vibrating and sending out waves in all directions; the length of the wave depends on the period of the vibration, and different lengths of wave produce the different colour sensations. Now through free ether all kinds of waves appear to travel at the same rate; not so through bound ether; inside matter the short waves are more retarded than the long, and hence the different sizes of waves can be sorted out by a prism. Now a free atom has its own definite period of vibration, like a tuning-fork has, and accordingly sends out light of a certain definite colour or of a few definite colours, just as a tuning-fork emits sound of a certain definite pitch or of a few different pitches called harmonics. By the pitch of the sound it is easy to calculate the rate of vibration of the fork; by the colour of the light one can determine the rate of vibration of the atom.

When we speak of the atoms vibrating, we do not mean that they are wagging to and fro as a whole, but that they are crimping themselves, that they are vibrating as a tuning-fork or or a bell vibrates; we know this because it is easy to make the free atoms of a gas vibrate. It is only in the gaseous state, indeed, that we can study the rate of vibration of an atom; when they are packed closely together in a solid or liquid, they are cramped, and all manner of secondary vibrations are induced. They then, no doubt, wag to and fro also, and in fact these constrained vibrations are executed in every variety, and the simple periodicity of the free atom is lost.

To study the free atoms we take a gas—the rarer the better—heat it, and then sort out the waves it produces in the ether by putting a triangular prism of bound ether in their path.

Why the bound ether retards different waves differently, or *disperses* the light, is quite unknown. It is not easy accurately to explain refraction, but it is extremely difficult to explain dispersion. However, the fact is undoubted, and more light will doubtless soon fall upon its theory.

The result of the prismatic analysis is to prove that every atom of matter has its own definite rate of vibration, as a bell has; it may emit several colours or only one, and the number it emits may depend upon how much it is struck (or heated), but those it can emit are a perfectly definite selection, and depend in no way on the previous history of the atom. Every free atom of sodium, for instance, vibrates in the same way, and has always vibrated in the same way, whatever other element it may have been at intervals combined with, and whether it exists in the sun or in the earth, or in the most distant star. The same is true of every other kind of matter, each has its own mode of vibration which nothing changes; and hence has arisen a new chemical analysis, wherein substances are detected simply by observing the rate of vibration of their free atoms, a branch of physical chemistry called spectrum analysis.

The atoms are small bodies, and accordingly vibrate with inconceivable rapidity.

An atom of sodium vibrates 5×10^{14} times in a second; that is, it executes five hundred million complete vibrations in the millionth part of a second.

This is about a medium pace, and the waves it emits produce in the eye the sensation of a deep yellow.

4×10^{14} corresponds to red light, 7×10^{14} to blue.

An atom of hydrogen has three different periods, viz. 4·577, 6·179, and 6·973, each multiplied by the inevitable 10^{14}.

Atoms may indeed vibrate more slowly than this, but the retina is not constructed so as to be sensible of slower vibrations; however, thanks to Capt. Abney, there are ways now of photographing the effect of much slower vibrations, and thus of making them indirectly visible; so we can now hope to observe the motion of atoms over a much greater range than the purely optical ones and so learn much more about them.

The distinction between free and bound ether is forced on our notice by other phenomena than those of light. When we come to electricity, we find that some kind of matter has more electricity associated with it than others, so that for a given electromotive force we get a greater electric displacement; that the electricity is, as it were, denser in some kinds of matter than in others. The density of electricity in space being 1, that inside matter is called K, the specific inductive capacity. In optics the density of the ether inside matter was μ^2. These numbers appear to be the same.

Is the ether electricity then? I do not say so, neither do I think that in that coarse statement lies the truth; but that they are connected there can be no doubt.

What I have to suggest is that positive and negative electricity together may make up the ether, or that the ether may be sheared by electromotive forces into positive and negative electricity. Transverse vibrations are carried on by shearing forces acting in matter which resists them, or which possesses rigidity. The bound ether inside a conductor has no rigidity; it cannot resist shear; such a body is opaque. Transparent bodies are those whose bound ether, when sheared, resists and springs back again; such bodies are dielectrics.

We have no direct way of exerting force upon ether at all; we can, however, act on it in a very indirect manner, for we have learnt how to arrange matter so as to cause it to exert the required shearing (or electromotive) force upon the ether associated with it. Continuous shearing force applied to the ether in metals produces a continuous and barely resisted stream of the two electricities in opposite directions, or a conduction current.

Continuous shearing force applied to the ether in transparent bodies produces an electric displacement accompanied by elastic resilience, and thus all the phenomena of electric induction.

Some chemical compounds, consisting of binary molecules, *distribute* the bound ether of the molecule, at any rate as soon

[1] A lecture by Prof. Oliver Lodge at the London Institution, on December 28, 1882. Continued from p. 306.

as it is split up by dissociation; and, instead of each nascent radicle or atom taking with it neutral ether, one takes a certain definite quantity of positive, the other the same amount of negative, electricity. In the liquid state the atoms are capable of locomotion; and a continuous shearing force applied to the ether in such liquids causes a continual procession of the matter and associated electricity, the positive one way, and the negative the other, and thus all the phenomena of electrolysis..

What I say about electricity, however, is not to be taken without salt, you will not regard it as recognised truth, but as a tentative belief of your lecturer's which may be found to be more or less, and possibly more rather than less, out of accordance with facts. I can only say that it hangs phenomena together, and that it has been forced upon my belief in various ways.

Now what about the free ether of space, is it a conductor of electricity? There are certain facts which suggest that it is, and Edlund has suggested that it is an almost perfect conductor. When a sun-spot or other disturbance breaks out on the sun, accompanied as it is, no doubt, by violent electric storms, the electric condition of the earth is affected, and we have auroræ and magnetic disturbances. Is this by induction through space? or can it be due to conduction and the arrival of some microscopic portion of a derived current travelling our way?

For my part I cannot think the ether a conductor. Maxwell has shown that conductors must be opaque, and ether is nothing if not transparent; one is driven, then, to conclude that what we call conduction does not go on except in the presence of ordinary matter—in other words, perhaps, that it is a phenomena more connected with bound ether than with free.

But now, looking back to Fresnel's hypothesis of the extra density of the ether inside gross matter, and also to the fact that it must be regarded as incompressible, the question naturally arises how can it be densified by matter or anything else? Perhaps it is not; perhaps matter only strains the ether towards itself, thus slackening its tension, as it were, inside bodies, not producing any real increase of density; and this is roughly McCullagh's form of the undulatory theory. In this form gravitation may be held to be partially explained; for two bodies straining at the ether in this way will tend to pull themselves together. In fact Newton himself pointed out that gravitation could be produced if only matter exerted this kind of strain on all pervading ether, the tension varying as the inverse distance.

He did not follow the idea up, however, because he had then no other facts to confirm him in his impression of the existence of such an ether, or to inform him concerning its properties. We now not only feel sure that an ether exists, but we know something of its properties; and we also have learnt from light and from electricity, that some such action between matter and ether actually occurs, though how or why it occurs we do not yet know. I am therefore compelled to believe that this is certainly the direction in which an ultimate explanation of gravitation and of cohesion is to be looked for.

In thinking over the Fresnel and McCullagh forms of the undulatory theory, with a view to the reconciliation between them which appears necessary and imminent, one naturally asks, is there any such clear distinction to be drawn between ether and matter as we have hitherto tacitly assumed? may they not be different modifications, or even manifestations, of the same thing?

Again, when we speak of atoms vibrating, how can they vibrate? of what are their parts composed?

And now we come to one of the most remarkable and suggestive speculations of modern times—a speculation based on this experimental fact, that the elasticity of a solid may be accounted for by the motion of a fluid; that a fluid in motion may possess rigidity.

I said that rigidity was precisely what no fluid possessed; at rest this is true; in motion it is not true.

Consider a perfectly flexible india-rubber O-shaped tube full of water; nothing is more flaccid and limp. But set the water rapidly circulating, and it becomes at once stiff; it will stand on end for a time without support; kinks in it take force to make, and are more or less permanent. A practicable form of this experiment is the well-known one of a flexible chain over a pulley, which becomes stiff as soon as it is set in rapid motion.

This is called a vortex filament, and a vortex is a thing built up of a number of such filaments. If they are arranged parallel to one another about a straight axis or core, we have a vortex cylinder such as is easily produced by stirring a vessel of water, or by pulling the plug out of a wash-hand basin; or such as are made in the air on a large scale in America, and telegraphed over here, when they are called "cyclones," or "depressions." The *depression* is visible enough in the middle of revolving water. These vortices are wonderfully permanent things, and last a long time, though they sometimes break up unexpectedly.

Vortices need not have straight cores, though they may have cores of various ring forms, the simplest being a circle. To make a vortex ring, we must take a plane disk of the fluid, and at a certain instant give to every atom in the disk a certain velocity forward, graduating the velocity according to its distance from the edge of the disk. We kave as yet no means of doing this in a frictionless fluid, bnt with a fluid such as air and water it happens to be easy; we have only to knock a little of the fluid suddenly out of a box through a sharp-edged hole, and the friction of the edges of the hole does what we want. The central portion travels rapidly forward, and returns round outside the core, rolling back towards the hole. But the impetus sends the whole forward, and none really returns; it rolls on its outer circumference as a wheel rolls along a road. In a perfect fluid it need not so roll forward, as there would be no friction, but in air or water a vortex-ring has always a definite forward velocity, just as a locomotive driving-wheel has when it does not slip on the rails.

We have in these rings a real mass of air moving bodily forward, and it impinges on a face or a gas flame with some force. It is differentiated from the rest of the atmosphere by reason of its peculiar rotational motion.

The cores of these rings are elastic—they possess rigidity; the circular is their stable form, and if this is altered, they oscillate about it. Thus when two vortex rings impinge or even approach fairly near one another, they visibly deflect each other, and also cause each other to vibrate.

The theory of the impact or interference of vortex rings whose paths cross, but which do not come very near together has been quite recently worked out by Mr. J. J. Thomson. It is quite possible to make the rings vibrate without any impact, by serrating the opening out of which they are knocked. The simplest serration of a circle turns it into an ellipse, and here you have an elliptic ring oscillating from a tall to a squat ellipse and back again. Here is a four-waved opening, and the vibrations are by this very well shown. A six-waved opening makes the vibrations almost too small to be perceived at a distance but still they are sometimes distinct.

The rings vibrate very much like a bell vibrates, perhaps very much like an atom vibrates. They have rigidity, although composed of fluid; they are composed of fluid in motion. These vortices, are imperfect they increase in size, and decrease in energy; in a perfect fluid they would not do this, they would then be permanent and indestructible, but then also you would not be able to make them.

Now does not the idea strike you that atoms of matter may be vortices like these—vortices in a perfect fluid, vortices in the ether. This is Sir William Thomson's theory of matter. It is not yet proved to be true, but is it not highly beautiful? a theory about which one may almost dare to say that it deserves to be true. The atoms of matter according to it are not so much foreign particles imbedded in the all-pervading ether as portions of it differentiated off from the rest by reason of their vortex motion, thus becoming virtually solid particles, yet with no transition of substance; atoms indestructible and not able to be manufactured, not mere hard rigid specks, but each composed of whirling ether; elastic, capable of definite vibration, of free movement, of collision. The crispations or crimpings of these rings illustrate the kind of way in which we may suppose an atom to vibrate. They appear to have all the properties of atoms except one, viz. gravitation; and before the theory can be accepted, I think it must account for gravitation. This fundamental property of matter cannot be left over to be explained by an artificial battery of ultra-mundane corpuscles. We cannot go back to mere impact of hard bodies after having allowed ourselves a continuous medium. Vortex atoms must be shown to gravitate.

But then remember how small a force gravitation is. Ask any educated man whether two pound-masses of lead attract each other, and he will reply no. He is wrong, of course, but the force is exceedingly small. Yet it is the aggregate attraction of trillions upon trillions of atoms; the *slightest* effect of each upon the ether would be sufficient to account for gravitation; and no one can

say that vortices do not exert some such residual, but uniform, effect on the fluid in which they exist, till second, third, and every other order of small quantities have been taken into account, and the theory of vortices in a perfect fluid worked out with the most final accuracy.

At present, however, the Thomsonian theory of matter is not a verified one, it is, perhaps, little more than a speculation, but it is one that it is well worth knowing about, working at, and inquiring into. It may stand or it may fall, but if it is the case, as I believe it is, that our notions of natural phenomena, though they often fall short, yet never exceed in grandeur the real truth of things, how splendid must be the real nature of matter if the Thomsonian hypothesis turns out to be inadequate and untrue.

I have now endeavoured to introduce you to the simplest conception of the material universe which has yet occurred to man. The conception that is of one universal substance, perfectly homogeneous and continuous and simple in structure, extending to the furthest limits of space of which we have any knowledge, existing equally everywhere. Some portions either at rest or in simple irrotational motion transmitting the undulations which we call light. Other portions in rotational motion, in vortices that is, and differentiated permanently from the rest of the medium by reason of this motion.

These whirling portions constitute what we call matter; their motion gives them rigidity, and of them our bodies and all other material bodies with which we are acquainted are built up.

One continuous substance filling all space: which can vibrate as light; which can be sheared into positive and negative electricity; which in whirls constitutes matter; and which transmits by continuity, and not by impact, every action and reaction of which matter is capable. This is the modern view of the ether and its functions.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—Lord Rayleigh has resumed his course of lectures on Electrical Measurements.

Dr. Gaskell's lectures this term deal with the Physiology of the Circulation; Mr. Langley is lecturing on the Physiology of Muscle and Nerve, and the Histology and Pathology of the Secretory Organs.

SCIENTIFIC SERIALS

Transactions of the New York Academy of Sciences, Nos. 2-5, 1881-82.—Outlines of the geology of the North-eastern West India Islands, by Prof. Cleve.—The excavation of the bed of the Kaaterskill, New York, by Dr. Julien.—On the cell-doctrine and the bioplasson doctrine, by Prof. Elsberg.—The discovery of the North Pole practicable, by Commander Cheyne.—The volcanic tuffs of Challis, Idaho, and other western localities, by Dr. Jullien.—The mammoth cave of Kentucky, by Mr. Stevens.—On the determination of the heating-surface required in steam pipes employed to produce any required discharge of air through ventilating chimneys, by Prof. Trowbridge.—On a peculiar coal-like transformation of peat, recently discovered at Scranton, Penn., by Prof. Fairchild.—The parallel drift-hills of Western New York, by Dr. Johnson.—Hypothetical high tides as agents of geological action, by Dr. Newberry.—The international time-system, by Prof. Rees. The moral bearing of recent physical theories, by Prof. Martin.—The discovery of emeralds in South Carolina, by Mr. Hidden.—Obituary notice of Prof. J. W. Draper.—On the behaviour of steam in the steam-engine cylinder, and on curves of efficiency, by Prof. Thurston.—Stereoscopic notes, by Prof. Hines.—A new reversible stereoscope, by Mr. Stevens.—Diphenylamine-acrolein, by Prof. Leeds.

Annalen der Physik und Chemie, No. 1, 1883.—On the radiometer, by E. Pringsheim.—A wave-length measurement in the ultra-red solar spectrum, by the same.—Fluorescence according to Stokes' law, by E. Hagenbach.—The isogyrous surfaces of doubly-refractive crystals; general theory of the curves of like direction of vibration, by E. Lommel.—On the heat-conducting power of liquids, by L. Graetz.—On the ratio of the specific heats in gases and vapours, by P. A. Müller.—The product of internal friction and galvanic conduction of liquids is constant with reference to the temperature, by L. Grossmann.—On M. Guébhard's proposed method of determination of equipotential lines, by H. Meyer.—Further researches on the relation of molecular refraction of liquid compounds to their chemical constitution, by H. Schröder.—On the preservation of oxygen gas in the zinc-gasometer, by J. Loewe.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, January 11.—"On the Skeleton of the Marsipobranch Fishes. Part I. The Myxinoids (*Myxine* and *Bdellostoma*)." By W. K. Parker, F.R.S. Abstract.

In their cranio-facial skeleton the Myxinoids are very remarkable; where segmentation is perfect in other fishy types there they only exhibit a lattice-work of continuous growth; in the median region of the skull-base, where other types show but little or only temporary distinctness of parts, these fishes develop and retain large independent cartilages.

The lamprey has a large superficial basket-work of soft cartilage (*extra-branchial*), and its gill-pouches keep this related to the rest of the structures of the mouth and throat. But in the Myxinoids the basket-work is *intra-branchial*, and corresponds to the system of segmented arches of the higher Cartilaginous, the Ganoid, and the Osseous fishes. But these non-segmented arches soon lose all relation to the branchial pouches, which are removed so far backwards that they begin under the *twentieth myotome;* whilst the end of the pericardium is under the *fortieth.*

In seeking light upon the primordial condition of the Vertebrata, one naturally looks to such forms as the Myxinoids. For in these types, even in the adult state, there are neither limbs nor vertebræ, and no distinction between head and body, except the beginning, in the head, of a cartilaginous skull; a *continuous structure*—not showing the least sign of secondary segmentation, and by far the greater part of which is in front of the notochord, or axis of the organism. But here our *gradational* work agrees with the *developmental*, for the continuous skull-bars constantly arise before the secondary cartilaginous segments that are found between the myotomes behind the head. Evidently, therefore, the early "Craniata" grew supports to the enlarged and subdivided front end of their neural axis, long before anything beyond strong fibrous septa were developed between the muscular segments of the body. As for the linear growth, the greater or less extension backwards of the main organs—circulatory, respiratory, digestive, urogenital—that, in the evolution of the primary form, was a thing to be determined by the "surroundings" of the type. "Thereafter as *they* may be" was the tentative idea in this case.

Certainly, in the Marsipobranchs and in their relations, the larval "Anura," we have the most archaic "Craniata" now existing; in these the organs may be extended far backwards in a vermiform creature, as in these low fishes, or kept well swung beneath the head—the body and tail together forming merely a propelling organ, as is seen in Tadpoles, especially the gigantic Tadpole of *Pseudis*.

Thus we see that in low limbless types there is no necessity for the development of more than fibrous "metameres"; but the vesicular brain, the suctorial lips, the branchial pouches, and the special organs of sense—these all call for support from some tissue more dense than a mere fibrous mat or web. In the *Myxinoids* we find that *four* special modifications of the connective tissue series are developed for the support of the properly *cephalic* organs, and for them only; thus these fishes are *Craniata*, but are not *Vertebrata;* that is, if we stick to the letter, which of course we do not.

At first some disappointment is felt, after careful study of these types, for, notwithstanding the low level in which they remain, they are mere specialised *Ammocœtes*, keeping on the same "platform" as the larval Lamprey; yet some parts of their organisation do undergo a marvellous amount of transformation, and are, indeed, as much specialised in conformity with their peculiar habits of life *as any Vertebrates whatever, the highest not excepted.*

Yet, on the whole, the Msxinoids are a sort of *Ammocœtine* type, whilst the transformed Ammocœte, the larval Lamprey, comes nearest to the untransformed Frog or Toad—the *Tadpole.* But the mere putting of this shows (suggests at any rate) what *losses* the fauna of the world has sustained during the evolution of the Craniate forms; *now*, the Myxinoids, Petromyzoids, and anurous Amphibia, must all be kept "within call" of each other; but the types that have been culled out between them